Searching for the missing mantles of disrupted asteroids: Evidence from an olivine-rich clast in the Vaca Muerta Mesosiderite

Conference or Workshop Item

SEARCHING FOR THE MISSING MANTLES OF DISRUPTED ASTEROIDS: EVIDENCE FROM AN OLIVINE-RICH CLAST IN THE VACA MUERTA MESOSIDERITE.

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Introduction: A well known problem, both in meteoritics, and from remote sensing observations of asteroids, is the apparent under representation of olivine-rich materials [1]. The basis of this problem is that complete melting of a chondritic asteroid should produce a layered body comprising a metallic core, a thick olivine-rich mantle and a thin basaltic crust [1]. Evidence from iron meteorites indicates that a large number of such fully differentiated bodies formed very early in solar system history [2]. The iron meteorite record provides evidence of approximately 60 such bodies: this is likely to be a significant under-sampling of the original population [1, 3]. Within the present meteorite flux, differentiated achondritic material is dominated by the pyroxene and plagioclase-rich HED suite (**H**owardite, **E**ucrite, **D**iogenite), with olivine-rich samples being rare. Likewise, only a small number of olivine-rich asteroids have been identified in the asteroid belt by remote sensing techniques [1].

What happened to all the olivine? A range of explanations have been advanced to account for this lack of olivine–rich material, these include: i) olivine-rich asteroids are "disguised" by space weathering, ii) the meteoritic record provides a poor indication of material present in the asteroid belt, iii) olivine-rich samples are preferentially destroyed by terrestrial weathering, iv) differentiated asteroids were disrupted early in solar system history with the mechanically weaker olivine-rich material being effectively destroyed by continuous communition [1]

Evidence from the stony irons: If olivine-rich material from asteroids was lost due to early disruption and subsequent comminution, one class of meteorites that might be expected to preserve traces of asteroidal mantles are the mechanically strong stony iron meteorites [4]. There is now reasonable evidence that Main-Group pallasites sample a single disrupted body and are impact-produced mixtures of mantle-derived olivine and core-derived metal [3,5]. The mesosiderites are more enigmatic, consisting of metal mixed with a range of crustal and sub-crustal lithologies. Although more abundant than in the HEDs, olivine-rich materials are still rare in the mesosiderites. Therefore, mesosiderites appear to be predominantly a mixture of core and crustal materials without much of the intervening olivine-rich mantle [3,6]. To understand this paradox we are undertaking a study of olivine-rich clasts in mesosiderites. Presented below are the results from one large cm-sized clast identified in the Vaca Meurta mesosiderite.

Vaca Meurta olivine-rich clast: A cut slice (~3mm thickness) of an olivine-rich clast in Vaca Muerta was acquired by one of us (HH) from a dealer. The original size and shape of the clast are unknown, but it appears to have been somewhat ovoid and at least 5cm in diameter. A thin 2-3mm layer of enclosing, finer-grained metal-rich matrix material is present along one edge. A polished thin section was prepared from the clast and mineral analyses were undertaken using a FEI Quanta 200 3D FIBSEM and Cameca SX100 microprobe. Samples from the clast were removed for oxygen isotope analysis by infrared laser-assisted fluorination [7].

In thin section the clast consists predominately of relatively fresh, angular olivine up to 1cm in diameter showing a well developed cataclastic texture (Fig.1). Olivines display distinct undulose extinction and broad polysynthetic twins. The interstices between the larger olivine grains are filled by finer grained angular olivine enclosed by sulphide (Fig 2). There is evidence of some secondary terrestrial alteration along fractures in the olivines, but in general the clast appears to be relatively fresh. Olivines are essentially homogeneous with a composition of $Fo_{88.7-89.5}$.

Oxygen isotope results. Two replicate analyses of material taken from the interior of the clast gave the following oxygen isotope composition: δ^{17}O 1.361 ±0.039‰; δ^{18}O 3.063 ±0.070‰; Δ^{17}O(Linear) -0.245 ±0.002‰ (Fig. 3). Analysis of material from the exterior of the clast gave more variable results with somewhat less negative values for Δ^{17}O (Linear), which may reflect secondary alteration. Further work is in progress to address this issue.

Origin of the Vaca Muerta clast. The oxygen isotope composition of the olivine-rich clast plots on the extension of the mass fractionation line for the mesosiderites and below that for the pallasites (Fig.3). This

This suggests that it is co-genetic with other silicate-bearing clasts in the mesosiderites and not a xenolithic fragment of pallasite-derived material. Olivine in the Vaca Muerta clast is at the Fo-rich end of the mesosiderite range (~$Fo_{58\text{-}92}$), but comparable to that found in Main-Group pallasites (~Fo_{88}) [3]. The HED-related dunite NWA 2968 appears to have a similar coarse-grained texture to that of the Vaca Muerta clast, but has somewhat more Fo-rich olvines (~Fo_{93}) [8]. One possibility is that the olivine clast represents a fragment of the olivine-rich mantle excavated during the mesosiderite forming impact event. The absence of large quantities of such clasts may be because this event did not result in total disruption of the parent body. On the basis of its oxygen isotope composition it would seem unlikely that the olivine-rich clast was part of the impactor. However, this possibility, although remote, cannot be excluded.

Conclusions. The Vaca Muerta clast may represent mantle material from the mesosiderite parent body. It suggests that the mesosiderite-forming event may have been of sufficient size to sample material from deep structural levels, but did not cause total parent body disruption. HEDs and mesosiderites have closely similar oxygen isotope compositions [9] and it is therefore possible that the mesosiderites formed during the same postulated 3.5 Gyr event on Vesta that created the Vestoids [10]. If this is not the case another large impact event on a distinct differentiated asteroid is required. In view of their abundance in the early solar system this is not as much of a coincidence as it might seem [1,2,3]. The Vaca Muerta clast again indicates that preservation of asteroidal olivine-rich material was not commonplace and may require relatively unique circumstances.

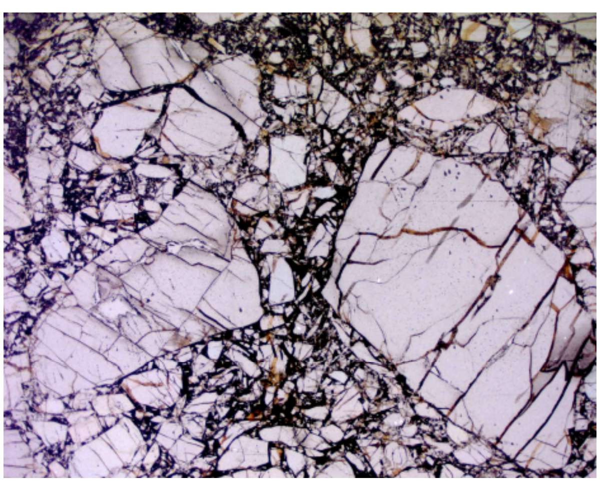

Fig 1. Vaca Muerta olivine-rich clast showing cataclastic textured olivines in a dark sulphide-rich matrix. (plane polarized light. Field of view 7mm)

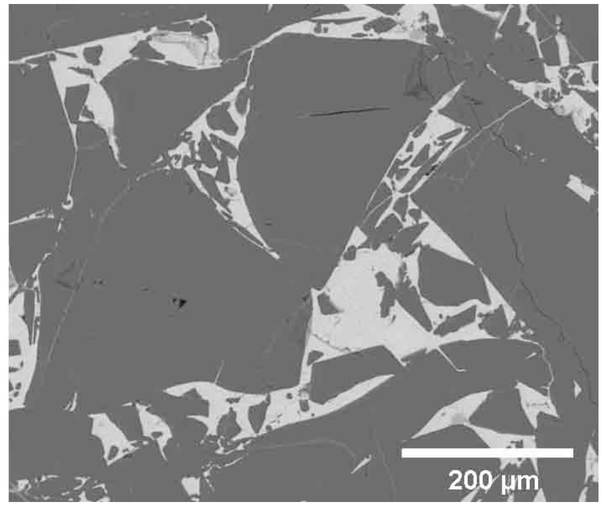

Fig 2. Backscattered electron image of Vaca Muerta olivine-rich clast. Angular olivines are enclosed in a sulphide-rich matrix.

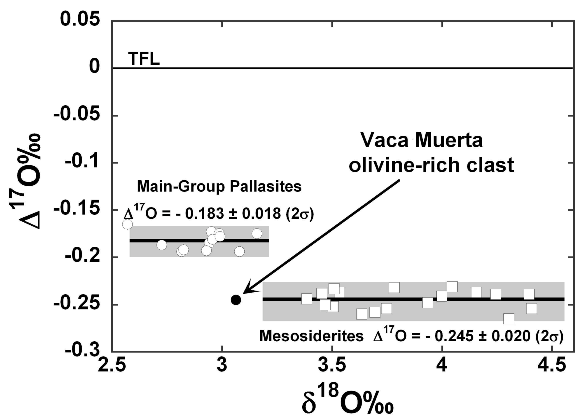

Fig 3. Oxygen isotope composition of Vaca Muerta olivine-rich clast. Mesosiderite and pallasite data from [9].

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